INDIANA DEPARTMENT OF TRANSPORTATION

INTER-DEPARTMENT COMMUNICATION

Standards Section ***C*** *Room N642*

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DESIGN MEMORANDUM No. 03-02
TECHNICAL ADVISORY

TO: **All Design, Operations, and District Personnel, and Consultants**

FROM: ***/s/ Anthony L. Uremovich***
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SUBJECT: **Design Guidelines for Three-Sided Drainage Structures**

SUPERSEDES: **Design Memorandum No. 01-11 Technical Advisory**

EFFECTIVE: **September 16, 2003, Letting**

A. Introduction

These guidelines should be used for all three-sided drainage structures on both INDOT projects and federally funded LPA projects. Recurring Special Provisions 723-R-282 and 723-R-282f have been revised to complement these guidelines. The revised provisions are attached hereto.

B. Structure Sizing and Selection

If the project is on a state-maintained route and the structure qualifies as a bridge or a stand-alone "small structure replacement," the Design Division's Hydraulics Unit will furnish the required minimum size for both the flat-topped and the arch structure in the hydraulic recommendations letter. The designer will choose the most appropriate alternate for the structure layout scheme shown on the plans and reference, by note, the other alternate. If the project is one for which the Hydraulics Unit has not prepared a hydraulic recommendation, the designer will determine the hydraulic size for both alternates.

The hydraulic recommendations will include the Q100 elevation, the assumed flow line elevation, the required span and the required waterway opening for both structure alternates. The designer will select the rise of the structure for both alternates. The minimum desirable freeboard requirement will be 0.3 m (1 ft) for both an arch structure and a flat-topped structure with the low structure elevation determined at the structure centerline for both alternates. If the designer elects to use a freeboard less than that specified in the hydraulic recommendations letter, he or she should obtain the concurrence of the Hydraulics Unit Supervisor.

Figure 03-02A should be used as guidance for determining the acceptable three-sided structure alternates to show on the plans.

Case	Freeboard Specified	Acceptable Structure Alternates to be Shown on Plans
1	$\geq$ 0.3 m (1 ft)	Both flat-topped and arch
2	0 < Fbd. < 0.3 m (1ft)	Generally, flat-topped only unless Hydraulics Unit Supervisor approves both alternates
3	$\leq$ 0	Both flat-topped and arch

DETERMINATION OF ACCEPTABLE
THREE-SIDED STRUCTURE ALTERNATES

Figure 03-02A

The arch structure will generally have a greater span requirement than the flat-topped structure where it is used with less than 0.6 m (2 ft) of freeboard. The arch structure will not be included as an alternate in the hydraulics recommendation letter if its required span exceeds that of the flat-topped alternate by more than 1.2 m (4 ft).

A structure designed with a profile grade and corresponding freeboard meeting Case 2 will not be permitted to be redesigned to a higher profile grade to comply with Case 1 if the project is beyond the preliminary field check stage.

If the arch structure is the only option permitted, the designer must obtain approval for use of a proprietary product.

Where the required structure span exceeds 9.14 m (30 ft), the Hydraulics Unit will also provide the required waterway opening for a spill-through bridge. The designer will size an appropriate bridge and perform an economic comparison between the bridge and the three-sided structure options.

The metric equivalents and english dimensions shown in Figure 03-02B for spans and Figure 03-02C for rises should be used for designating each three-sided structure in the Schedule of Pay Items. The plans should show the structure size in meters (feet). The plan dimensions in meters should be shown to two decimal places.

Meters	Feet	Milli-meters	Inches	Meters	Feet	Milli-meters	Inches
3.66	12	3660	144	7.31	24	7310	288
3.96	13	3960	156	7.62	25	7620	300
4.26	14	4260	168	7.92	26	7920	312
4.57	15	4570	180	8.23	27	8230	324
4.87	16	4870	192	8.53	28	8530	336
5.18	17	5180	204	8.84	29	8840	348
5.48	18	5480	216	9.14	30	9140	360
5.79	19	5790	228	9.75	32	9750	384
6.10	20	6100	240	10.36	34	10 360	408
6.40	21	6400	252	10.97	36	10 970	432
6.71	22	6710	264	12.80	42	12 800	504
7.01	23	7010	276	14.63	48	14 630	576

METRIC AND ENGLISH SPAN DESIGNATIONS

Figure 03-02B

Meters	Feet	Milli-meters	Inches	Meters	Feet	Milli-meters	Inches
1.22	4	1220	48	3.15	10’-4”	3150	124
1.52	5	1520	60	3.25	10’-8”	3250	128
1.83	6	1830	72	3.35	11’	3350	132
2.13	7	2130	84	3.45	11’-4”	3450	136
2.44	8	2440	96	3.56	11’-8”	3560	140
2.74	9	2740	108	3.66	12	3660	144
3.05	10	3050	120	---	---	---	---

METRIC AND ENGLISH RISE DESIGNATIONS

Figure 03-02C

Rises greater than 3.05 m (10 ft) should be specified in 0.10 m or 100 mm, or 0.11 m or 110 mm (4 in.) increments as in the examples shown above.

C. Segment Configuration and Skew

Skews should generally be in 5° intervals, although 1° intervals are permissible where necessary.

It is not necessary for the designer to determine the exact number and length of segments. The final structure length and segment configuration will be determined by the fabricator and may deviate from that implied by the plans. However, a minimum horizontal clearance of 1.8 m (6'-0") must exist between the front face of guardrail and the outside face of the structure headwall where the drainage structure end is within the clear zone.

Square segments are generally more economical even if the structure is skewed. Laying out the structure with square segments will result in the greatest right-of-way requirement and thus allow ample space for any potential redesign by the contractor to another segment configuration.

For a structure with a skew of less than 15°, structure segments may be laid out square or skewed. Skewed segments are generally preferred for a structure of less than 25 m (80 ft) in length. Square segments are preferred for a longer structure. However, skewed segments have a greater structural span. A structure with a skew of greater than 15° requires additional special analysis per the AASHTO *Standard Specifications for Highway Bridges*. Skewed segments and the special analysis both contribute to higher structure cost.

The preferred layout scheme for an arch structure with a skew of greater than 15° should assume square segments with a sloping top of headwall to yield the shortest possible wingwalls. For a structure with a skew of greater than 15°, structure segments should be laid out square. If hydraulic conditions dictate the use of a flat-topped structure only, the segments may be laid out skewed if the structure is relatively short.

According to industry publications, a significant number of flat-topped structures are built with skewed segments, i.e., segments shaped, in plan view, like parallelograms. However, several INDOT structures have been redesigned to use only square segments. Where a flat-topped structure is laid out with ends parallel to the roadway, skewed segments are implied by the designer.

Where an arch structure is laid out with skewed ends (headwalls parallel to the roadway), the skew will be developed within the end segments by varying the lengths of the legs as measured along the centerline of the structure. Generally, the maximum attainable skew is controlled by the difference between the full segment leg length as recommended by the arch structure fabricator and a minimum leg length of 0.6 m (2 ft).

If the roadway above the structure is to be constructed in two phases, the designer should propose a segment skew configuration compatible with the anticipated construction line between construction phases. Therefore, if the structure length is 25 m (80 ft) or greater, a unique special provision should be included to require the contractor to design and detail special segments or cast-in-place construction

required to conform to the construction line between phases. These details should be carefully reviewed by the designer when shop drawings are submitted.

D. Plan Requirements for Structure Layout and Detailing

The designer should select the most appropriate structure alternate for the structure layout scheme and show that alternate on the plans. The designer should use the span and rise for this alternate as a reference for the information required on the Title Sheet. The structure type to be shown on the Title, Layout, and General Plan sheets shall be Precast Reinforced Concrete Three-Sided Structure.

The General Plan should include a note as follows:

> [Metric-Units Project:] An alternate structure type with a ____ m span and a _____ m rise may be substituted for the structure indicated in the layout scheme.
>
> [English-Units Project:] An alternate structure type with a _____ ft span and a _____ ft rise may be substituted for the structure indicated in the layout scheme.

Where a flat-topped structure is the only option permitted, the General Plan should include a note as follows:

> A three-sided arch structure will not be permitted at this location.

The designer should provide the elevations on the General Plan or other detail sheet as follows:

> Q100,
> flow line, at both structure ends and the roadway centerline
> the low structure at the centerline of the structure,
> the tops of headwalls, and
> the tops of wingwalls.

The assumed elevations of the top of the footing and the base of the structure leg should also be given. For structure layout purposes, a 0.6 m (2 ft) footing thickness should be assumed with the base of the structure leg seated 50 mm (2 in.) below the top of the footing elevation. With the bottom of the footing placed at the standard depth of 1.2 m (4 ft) below the flow line elevation, the base of the structure leg should therefore be shown as 0.65 m (2’-2”) below the flow line. Exceptions to the 1.2 m (4 ft) depth will occur where the anticipated footing thickness is known to exceed 0.6 m (2 ft), where the footing must extend to rock, or where poor soil conditions dictate that the footing be deeper.

The footing should be kept level whenever possible. If the stream grade prohibits a level footing, the wingwall footings must be laid out to be constructed on the same plane as the structure footings.

The designer should indicate the structure length and the flare angle, and the length and height of wingwalls. For a skewed structure, the wingwall geometrics should be determined for each individual wing. The side slope used to determine the wing length should be clearly shown on the plans.

The pay length for a skewed structure should always be measured along the skew at the centerline of the structure.

Generally, a structure should extend to a point where the headwall height can be kept to a minimum, preferably 0.3 m (1 ft). All headwalls should have standard-length-post guardrail protection unless the structure cover does not allow it. Where structure cover does not allow a standard headwall and standard-length-post guardrail installation, the designer should see the INDOT Standard Drawings for other options, and show the selected low cover guardrail option on the plans. The designer must ensure that a minimum of 1.8 m (6'-0") of clearance exists horizontally between the face of guardrail and the outside face of the structure headwall.

For shallow cover of less than 500 mm (1'-8") as measured at the base of the roadside barrier and a structure width of greater than 7400 mm (24'-3"), the designer should use a concrete barrier railing or type CF-1 bridge railing mounted on the structure headwall.

Where a concrete barrier railing is shown on the plans, the epoxy coated reinforcing steel and concrete for the railing should be billed and paid for separately from the three-sided structure. Where a CF-1 railing is shown on the plans as integral with the headwall, the epoxy coated reinforcing steel required for the railing should be shown in the headwall in accordance with Standard Drawing 706-BRTM-01. The epoxy coated reinforcing steel, railing anchors, and concrete in the headwall should not be billed, but the entire headwall itself will be included in the cost of the structure. A pay item should be included for the CF-1 railing to cover the cost of the portion of the railing that is mounted on top of the headwall.

If the necessary height of the structure legs exceeds 3.05 m (10 ft), the designer should show pedestals in the structure elevation view. For illustration purposes, the pedestals should be drawn approximately 0.6 m (2 ft) wide, but the dimensions and details should not be shown. The pedestal height should be included in the rise dimension specified in the pay item.

The design and details for footings or base slabs, wingwall footings, wingwalls, and headwalls will be provided by the structure manufacturer when the shop drawings are submitted. The designer who prepared the contract plans will review the design calculations and shop drawings. For a federal-aid local agency project, such documents are subject to approval by the local agency or its design consultant.

The designer should refrain from showing details on the plans such as wingwall anchor systems that suggest a proprietary product. Such details should be shown on the shop drawings.

The cost of the structure and wingwall footings will be included in the cost of the structure and the wingwall, respectively. Headwalls and foundation excavation will also be included in the cost of the structure.

The General Plan should include a Design Data section showing the following:

> Designed for HS 20-44 loading in accordance with [current edition year] AASHTO Standard Specifications for Highway Bridges and all subsequent interim specifications.
>
> [Metric-Units Project:] Dead load increased 1.7 kN/m^2 for future wearing surface.
>
> [English-Units Project:] Dead load increased 35psf for future wearing surface.

E. Foundations

The allowable soil bearing pressure should be shown on the plans. If the footing is on piling, the ultimate pile bearing load should be shown.

A table should be included on the plans listing the soil parameters for wingwall design as follows:

> Angle of friction between wingwall footing and foundation soil (δ),
> Angle of internal friction of the foundation soil (ϕ),
> Ultimate cohesion of foundation soil (C),
> Ultimate adhesion between foundation soil and concrete (C_A).

These soil parameters will be provided in the geotechnical report for the three-sided structure. If the geotechnical report is lacking this information, it should be requested from the Materials and Tests Division's Geotechnical Section.

Where a pile footing is required, the designer should determine the type and size of pile and the required pile spacing, indicate any piles that are to be battered, and show all information on the plans. The final design of the pile cap will be performed by the fabricator and the details will be shown on the shop drawings as is the practice for other footing types. Payment for the pile cap will be included in the cost of the structure or the wingwall. The piling will be measured in meters (linear feet) and paid for separately in accordance with 701.15. If the geotechnical report recommends piling be used, the designer should re-evaluate the structure type selection versus a spill-through bridge in light of the added expense of a pile footing.

The plans for a three-sided structure should include a sheet showing the soil boring logs for the structure.

F. Backfill Requirements

The structure and wingwall backfill limits should be shown on the plans. The backfill limits should have a width of 0.45 m (1.5 ft) at the bottom of the footing and should extend upward at a slope rate of 1:4. The wingwall backfill should extend upward at 1:1 slope from the bottom of the wingwall footing. The structure fabricator will also be required to show the backfill limits on the shop drawings. The backfill pay limits should be based on the neat line limits shown on the plans.

Where there is less than 0.3 m (1 ft) of cover between the structure and the proposed pavement structure, the structure shall be backfilled with flowable backfill to the top of the vertical leg. If a flat-topped structure is specified, and the cover is less than 0.3 m (1 ft), the backfill above the structure should be shown as compacted aggregate base. If an arch structure is specified, and the cover is less than 0.3 m (1 ft), the backfill above the structure should be shown as structure backfill, with the top 150 mm (6 in.) shown as compacted aggregate base. The pavement design engineer should be consulted for the minimum pavement thickness to use above the structure.

Granular structure backfill should be used to backfill all wingwalls regardless of depth of cover for the structure. Riprap and geotextile should be used on the stream banks adjacent to the wingwalls.

G. Scour Considerations

The standard footing depth of 1.2 m (4.0 ft) below the flow line and the riprap protection as shown in Standard Drawings 714-CCSP-01 through -03 will suffice for scour protection in most routine installations.

Where the allowable soil bearing pressure is extremely low or where the stream velocity exceeds 3.0 m/s (10 ft/s) the designer should provide a concrete base slab instead of a conventional strip footing. Details of the base slab method of scour protection are shown on Standard Drawings 714-CCSP-04 and -05. For borderline cases, the designer should study the cost effectiveness of providing a base slab versus providing a strip footing with riprap scour protection. The input of district construction should be requested at the preliminary field check if the costs appear to be equal.

Figure 03-02D should be used to determine the type of scour protection required for three-sided structures, or channels. The riprap type and quantity should be shown on the plans.

MIN. AVG. STREAM VELOCITY m/s (fps)	MAX. AVG. STREAM VELOCITY m/s (fps)	RIPRAP AT STR.	RIPRAP AT OUTSIDE CURVED BEND IN CHANNEL	BASE SLAB CONCRETE AT STR.
$\leq$ 2 ($\leq$ 6.5)	N/A	Revet.	Class 1	Class B
> 2 (> 6.5)	< 3 (< 10)	Class 1	Class 2	Class B
N/A	$\geq$ 3 ($\geq$ 10)	N/A	Class 2	Class B

Note: The maximum average stream velocity at the structure may occur at a lesser event than the design storm if roadway overtopping is present during the design storm.

SCOUR PROTECTION OF CHANNEL
AT THREE-SIDED STRUCTURE

Figure 03-02D

If an INDR Floodway Construction, IDEM Water Quality 401, or a U.S. Army Corps of Engineers 404 permit application is required, the designer should incorporate the required scour quantities of riprap or cast-in-place concrete into the application. If one or more of these permits has already been granted, the designer must provide the quantities information to the Environmental Permits Coordinator. The Coordinator will then apply for a permit amendment.

H. Schedule of Pay Items

Payment for three-sided structures will be made under the following:

Pay Item.....Pay Unit Symbol

Structure, Precast Three-Sided, _____mm x _____mm.....m
span rise
(Structure, Precast Three-Sided, _____in. x _____in. ..... LFT)
span rise
723-06660 Wingwall.....m2 (SFT)

The pay item for each span and rise, of course, has its own code number. Once the designer has determined the correct pay items, he or she may get the correct pay item code numbers from the estimating software or the Contracts and Construction Division's Administrator Analyst. The specifications reference number for all of these pay items is 723.